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ORIGINAL ARTICLE

Parking problems in Abu Dhabi, UAE toward an intelligent parking management system "*ADIP: Abu Dhabi Intelligent Parking*"

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Abstract Car parking is a serious problem in Gulf Cooperation Council (GCC) countries in general and in United Arab Emirates (UAE) in particular. This problem has been associated with the exceptional growth in the number of cars, buses, trucks, and other modes of transportation over the past few decades. In Abu Dhabi (the capital city of UAE), finding a parking at some locations is a real challenge due to the lack of available parking slots in the city. In 2009, in order to organize the randomness in parking management in Abu Dhabi, Abu Dhabi City started implementing a new paid parking system inside the city, named MAWAQIF. This new system helps in reducing the parking problem in congested areas, yet has transferred the problem to less crowded areas in the city. Furthermore, the number of parking lots provided in the controlled areas isn't enough to satisfy the demand in these areas. This article concentrates on this direction and focuses on two aspects. First, a survey was prepared and distributed to 500 participants as a part of a project, in order to identify the scale of the parking problem in Abu Dhabi. Then, a technical framework for developing an intelligent mobile application for improving the indoor parking management system in Abu Dhabi was developed. Results indicate that the proposed mobile application will help in reducing the time wasted in searching for parking and will increase the efficiency of the parking system in Abu Dhabi.

1. Introduction

Much literature has proposed different architectures to help citizens in finding and searching for a free parking slot inside large cities by using smart urban systems. Yang et al. [9]

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presented a prototype system for smart parking services, based on wireless sensor networks; to effectively search for free parking slots. Low-cost wireless sensor network modules are deployed into each parking slot, equipped with one sensor node to detect the status of the parking lot and report it to the embedded web-server through the wireless sensor networks. Drivers can find vacant parking lots using their mobile devices. Trusiewicz and Legierski [7] proposed a system for parking slots reservation. They used Unstructured Supplementary Service Data (USSD) as a communication channel between the driver and the parking system. The proposed system is integrated with a communication service provider infrastructure; using Service Delivery Platform exposed APIs for a telecommunication network on the Internet. Bechini et al. [1], proposed a system in two phases. The first phase uses a mobile GPS system to determine the available parking spots that are categorized, based on occupancy using different colors. The second phase starts once the driver parks the car, through scanning the QR code that is in front of the parking slot area. This will automatically update the status and send updates via an information system to the user, through his/her mobile.

Grazioli et al. [3] presented a modular, service-oriented parking system that includes web applications for the parking operators and end users, as well as mobile applications for end users and parking controllers. The proposed system is integrated with Google Maps and allows the operators to draw parking areas and define their details. Furthermore, end users can be guided to the parking areas and controllers can monitor vehicles that have been parked in their areas. Wang and He [8] proposed a prototype, a Reservation-based Smart Parking System (RSPS), which is based on periodically learning the parking status from the sensor networks deployed in parking lots. Drivers can access this cyber-physical system through mobile devices and the Internet. Hanif et al. [4] proposed a smart parking system for commercial parking areas. The parking reservation system allows users to book their parking lots through Short Message Services (SMS) that will be processed by a wireless communication instrumentation device called a micro-RTU (Remote Terminal Unit) that will reply by a confirmation SMS message, giving reservation details such as the password and lot number.

In addition, a proposed methodology by Felix Caicedo [2] was made for predicting real-time parking space availability in Intelligent Parking Reservation architecture that consists of three subroutines to allocate simulated parking requests, estimate future departures, and forecast parking availability. This approach is based on a calibrated discrete choice model for selecting parking alternatives. The forecast improves as the system registers arrivals and departures. Thus, the forecast is adequate for potential distribution in real time, using different media such as the Internet, navigation systems, cell phones or GIS. Another contribution was made by Khang et al. [5], who investigated the problems of car parking system in Malaysia. They proposed a wireless mobile-based car parking system using an SMS service that enables drivers to receive information regarding the available parking spaces. The suggested system used a Breadth First Search (BFS) algorithm to find the nearest parking space by printing the specific parking lot ID on the ticket that the driver takes before entering the car park.

2. Methodological approach & data analysis

This section represents the main part in this article and it contains two major aspects: a survey to analyze the scope of the parking problem in Abu Dhabi, and the development of a mobile application to enhance the efficiency of the Abu Dhabi

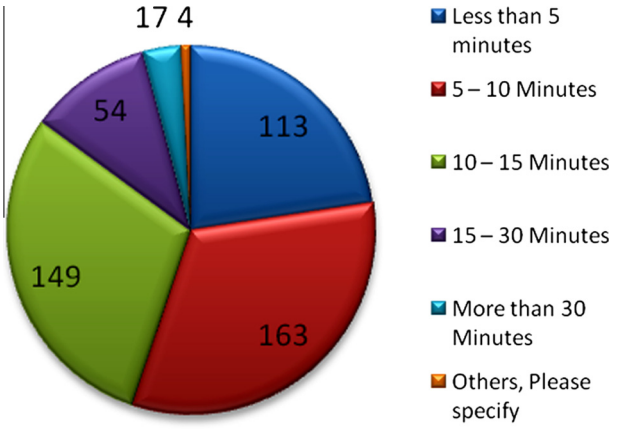


Figure 1 Searching time for a parking spot.

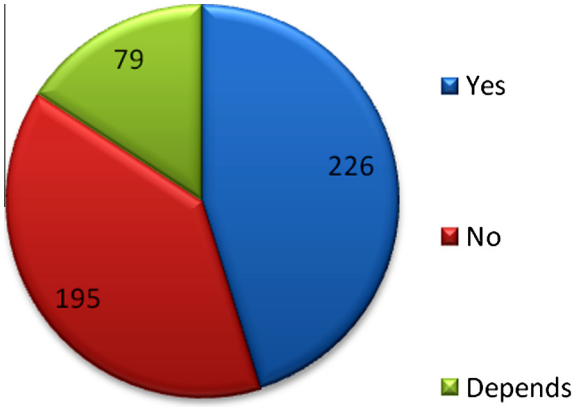


Figure 2 Number of people facing a problem in searching for a parking spot inside a mall.

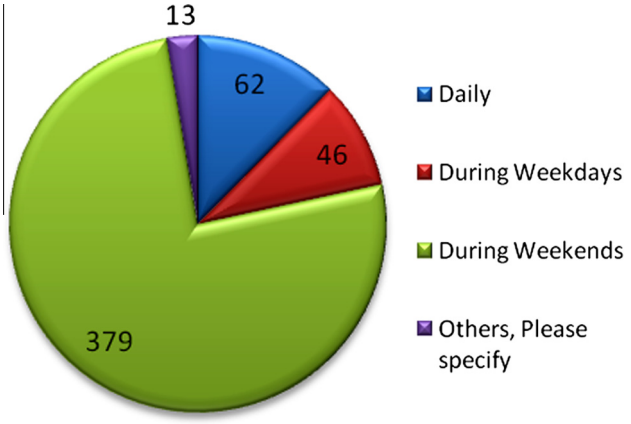


Figure 3 Frequency of visiting a mall per month.

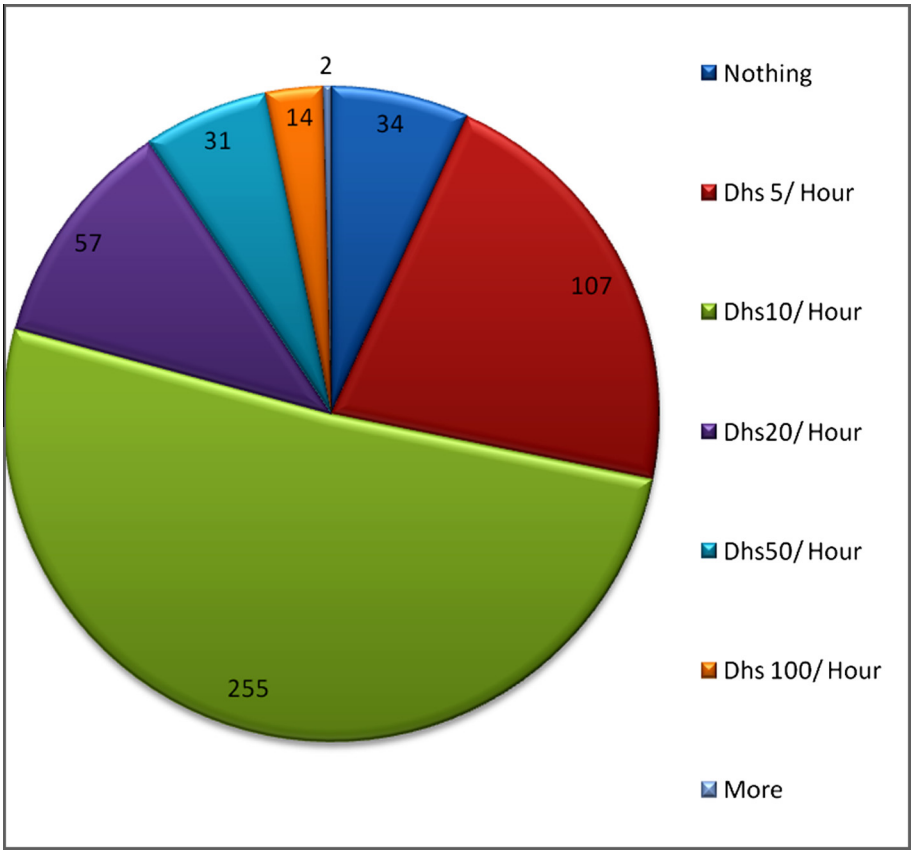


Figure 4 Loss value because of the wasted time searching for a parking spot.

parking management system, taking commercial malls as an example. This will be discussed in detail in the following two subsections.

A special survey was tailored to fit the scope of this paper, covering different issues related to the parking problem in Abu Dhabi. The survey is divided into two parts: background information and parking data. The background information collects data about some background or biographical aspect of the surveyed sample in order to compare groups of respondents. The parking section of the survey refers to the parking problem that people in the surveyed sample face when visiting a mall, restaurant, exhibition, or any other public area. It reflects the respondent's lost time taken up in finding a parking space and the appropriateness of the space available for his/her vehicle to park.

A total number of 500 surveys were distributed, filled and collected back from the surveyed sample. Numerical data and other related comments raised by the correspondent were collected and entered on Excel sheets for analysis. This section will show an in-depth analysis of the data set prepared based on the surveyed sample input, in order to draw important conclusions about the parking problem in Abu Dhabi and figure out how this input can be incorporated in our parking mobile application system. The age group 21–30 years old composes the majority in our sample, followed by the younger age group.

The second group of questions in the survey focuses on the parking problem. Starting with the frequency of visiting a mall per month, results show that the majority of the surveyed sample (379, about 76%) visits the mall during weekends. The weekend holiday period in Abu Dhabi is Friday and Saturday, so it is expected that most visits to the mall will be done during these two days, which will create traffic congestion at these locations and, hence, a severe parking problem. Focus on future parking studies should be given to weekends as the peak period. Another question was raised in the survey, to investigate further about the parking problem. The survey has revealed that more time is needed to search for a parking space over the weekend as compared to weekdays. This is related to the large demand encountered in malls over the weekend. Fig. 1 reports that the majority (163/500) took 5–10 min to find a parking space, followed by another significant number (149/500) with 10–15 min of searching time.

This means that for a majority of our sample (62%), the searching time is 15 min or less, during which they keep searching for a parking space. However, a small percentage (17 out of 500) took them more than half an hour to find a parking space, which indicates that finding a parking spot sometimes can be a real challenge (see Figs. 2, 5 and 6).

The last piece of the survey asked people to provide general comments about the parking problem in Abu Dhabi and how it can be solved. One of the most important comments raised by the surveyed sample was the desire to have a mobile application that can solve and reduce the time wasted in searching for a parking space. This paper, as shown in the coming sections, will present the development of such a mobile application that will help in solving the parking problem in Abu Dhabi, once implemented.

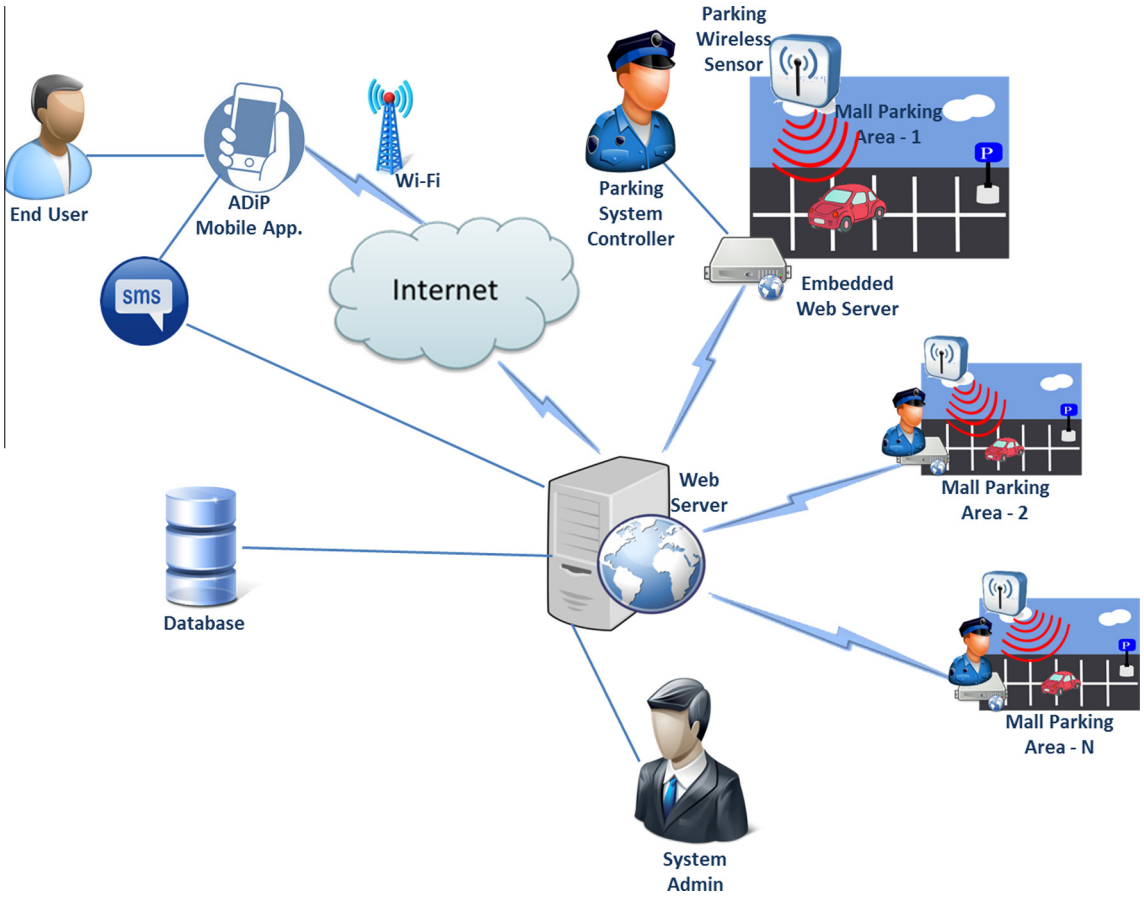


Figure 5 ADIP proposed architecture.

3. Feasibility analysis

3.1. Product feasibility

The overall appeal of this proposed product was evaluated among the surveyed people.

It was found that the majority of the respondents (226 out of 500, 45%) confirm that there is a real problem in searching for a parking space in the designated mall areas. This supports the need for our system to try to reduce the severity of such problems.

The main two components of the product feasibility are product desirability and product demand. In terms of the product desirability, the responses have indicated that this product solve a problem (find a parking slot in a mall parking). It is also reasonable and fills a gap in the market place especially that it is the only of its kind. On the other hand, the evaluation of the demand has shown a great impact among customers. e.g. the responses of the survey have shown that 97.4% of the people visit the mall weekly, and about 12.4% of them visit the mall on daily basis.

4. Abu Dhabi Intelligent Parking (ADIP) Mobile Application

As shown from the results of the previous survey, there is a great demand from the local community in Abu Dhabi to develop a mobile application system to enhance the efficiency of the existing parking management system. This section reviews the system architecture and design phase of our Abu Dhabi Intelligent Parking (shortly named as ADIP) mobile application, including algorithm development, technical development of the mobile application, mobile application user interface and, finally, future work.

The last question in our survey aimed to get some financial information on how much value do people think they are losing because of the wasted time they lose in searching for a parking space (Fig. 4). The results show that the majority (255 out of 500) equate this time loss with a money value of 10 Dirhams per hour, followed by 107 responses who consider it 5 Dirhams per hour. Some responses even go for over 100 Dirhams, which indicates that economic loss is another disadvantage resulting from the existing parking problem in Abu Dhabi.

5. ADIP proposed system architecture

The ADIP proposed system architecture is presented in this section, as shown in Fig. 3, which describes the architecture overview of the suggested system. The architecture is composed of the End User, the System Admin, the Parking System Controller, the mobile application, the Internet, the Web server, the Database, and Parking Wireless sensors.

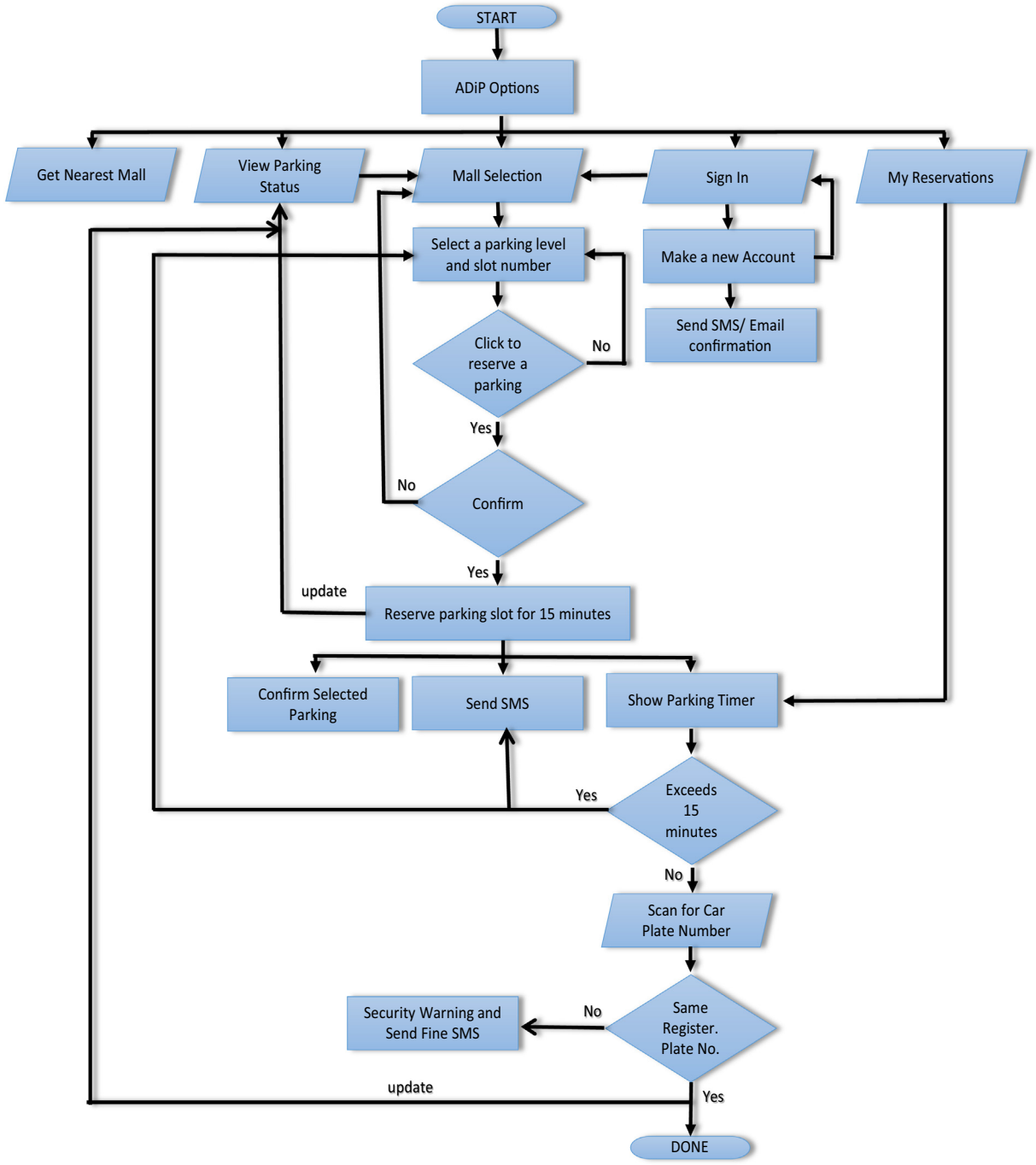


Figure 6 ADIP Algorithm.

ADIP Mobile Application Architecture consists of:

End user: Interacts with the Mobile Application (ADIP); such as find nearest mall, reserve a parking spot, check parking status, login/register into the system.

System admin: Controls the system and assures that data are well maintained and updated.

Parking system controller: Responsible for ensuring that the wireless sensors are working fine and the parking status is being updated, checking whether the car is parked in the right lot, making sure that all car parking plates are scanned for updating the system, and issuing fines and security warnings when a car is parked in a wrong reserved lot.

ADIP Mobile Application: A Graphical User Interface Android based mobile application that contains the following functions; get nearest mall, view parking status, mall selection, login/register, and check reservations (My Reservations).

Also, the mobile application, once logged in, will connect to the web server and will display real time information back to the end user containing the updated information about the parking.

Table 1 ADIP Mobile Application user interface design.

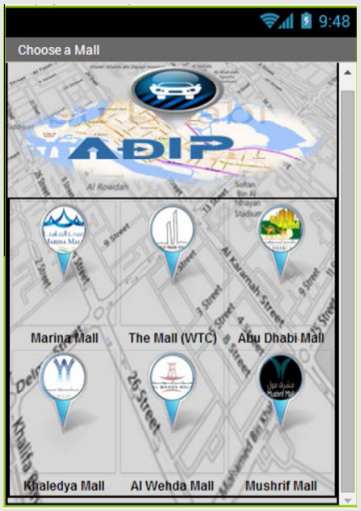
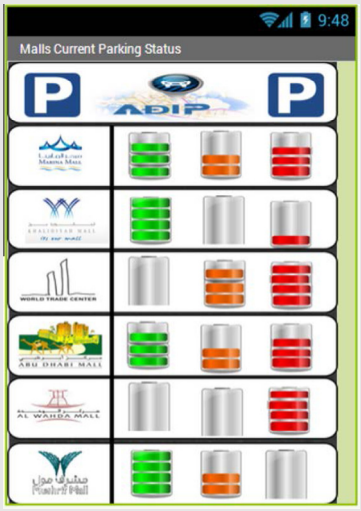
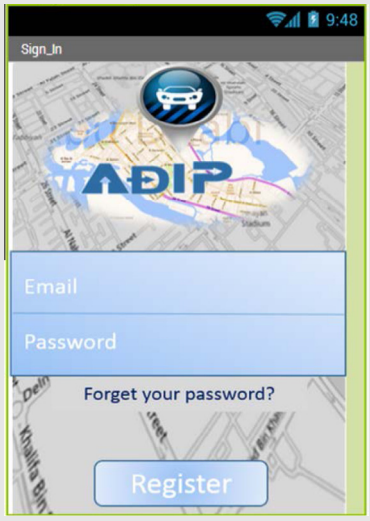
Figure	Description
 (A) *The ADIP main window* Once the user clicks the App icon, window (A) appears, which reflects the main window of the application, and then the user can click the Find icon in order to start using the application	 (B) *ADIP options window* the user has six main options to select from, as follows: – If the user clicks the **Nearest Mall** option, then a GPS system shows a map for the nearest mall, according to which the user current location will appear – If the user clicks the **Empty Mall parking**, then a new window will appear, showing the current parking status inside the different malls of Abu Dhabi City. The user can make a decision based on which mall has free parking occupancy, in order to visit and make the efficient parking reservation – If the user clicks the **Choose Mall** option, then a new window will open that allows the user to select a Mall in order to reserve a parking space – If the user clicks on the **Sign In** option, this will allow him/her to sign into the system or make a new account if they are driving another non-registered car. – If the user clicks on the **My Reservations** option, a list of user reservations in case of multiple parking reservations is done. – If the user clicks the **Parking Timer** option, then a time of reservation is displayed to remind the user about the remaining time for the reserved parking
 (C) *List of Abu Dhabi malls to make a selection to reserve a parking* From this window the user has the option to select any of the six famous malls inside Abu Dhabi Island in order to make the parking	 (D) *Malls parking occupancy status* Displays the parking occupancy status for each of the six malls. The status is being displayed as an indicator level for the three categories by

Table 1 (*continued*)

Figure	Description
reservation. The user can select any mall by clicking on the mall logo icon on the window	colors. The green color shows the current up-to-date percentage of free parking slots in each mall, while the orange indicator shows the current up-to-date percentage of reserved parking slots, and the red indicator shows the current up-to-date percentage of the fully occupied parking slots This window will assist the user to make an efficient selection as to which mall to visit, as it shows the parking up-to-date availability indicators in real time status
 (E) *Sign in and registration window* Sign In and Registration Window; the user has three options: 1. If the user is a new user, she/he must register by clicking the register button and filling out some information such as first name, surname, email address, mobile number, and car plate number. This information will be sent to a specialized database that is shared by the Department of Transport and Abu Dhabi Police. This will assure a smooth transaction process and that registered cars will be parked in the reserved parking slots before issuing a fine if the user's car violates the reserved parking. In addition, an SMS will be sent to the user to confirm his/her new account 2. If the user is already registered, she/he can login by the registered email address and password in order to use the registered car information for reserving parking 3. The user has an option to retrieve, through an SMS or email, the password, in case she/he forgets the password	 (F) *Making a parking reservation* Once the user selects a specific mall then a new window will display showing the available parking slots' numbers inside this mall. This will allow the user to select first the parking level she/he would like to park her/his car in (e.g. basement, level 1, level 2, ... according to the mall structure). Then it allows the user to select the available slot numbers by selecting from a list of parking numbers. At the end the user must click on the "Click To Reserve" button in order to confirm the reservation process. After the confirmation, a pop-up window will be displayed to confirm the reservation or to cancel. If the user selects confirm, window (G), otherwise the reservation will be canceled and the user will be returned to window (B)

(*continued on next page*)

Table 1 (*continued*)

Figure	Description
 (G) *Parking reserved confirmation*	 (H) *Reserved parking slot location*
After the user confirms his/her parking reservation option, a new window opens, showing that the reservation of the selected parking has been done for 15 min, and the occupancy status of the selected parking changes to an orange light to confirm the reservation. In addition, the timer displays indicate how much time is left for the reservation before changing the light status back to green Also, the window contains a button at the end, which displays once the path of the reserved parking slot location is clicked	Displays the path to the reserved parking slot. In this figure it displays the reserved parking number selected (134) in the Marina Mall, and the path to the slot, which is presented in dark blue with the number. Other slot colors appear in the map that reflect in real time the current parking occupancy status: the green color indicates the empty parking slot, the orange reflects the reserved slot, and the red reflects the occupied slot Once the designated vehicle reaches the reserved parking, the plate number will be scanned to check whether it matches the reservation information. If a match happens, the parking will turn to red and the car will park. Otherwise, a sound and/or paper warning will be issued to the driver to step away from the reserved parking. If the unauthorized driver parks illegally, then a fine will be issued to the driver and sent to the police database with a picture taken of his/her car

Internet: The global network that is mandatory to connect the mobile application with the web server to get the parking status updates.

Web server: Receives real time information from the embedded web servers in the parking slot area, sends this information to the mobile application (ADIP), saves this information into the database, checks the end user related information, once logged in into the system, updates the reserved time, sends a confirmation SMS to the end user, and sends a time update to the end user. Database: Saves the parking information and saves the end user identification information.

Parking wireless sensors: Collects parking status data, checks reserved parking time, Sends parking information to the web server through embedded webservers (1–N including all malls) connected to them, updates and changes the car parking color status (Green, Orange, Red).

6. ADIP Mobile Application development: a technical view

This section presents the design and implementation technical criteria of our mobile application ADIP. Software design and implementation are the two core sequence phases for any software development life cycle process after the planning and analysis. In ADIP, these phases were accomplished using the Google App Inventor system for Android Mobiles [6]. The Google App Inventor is an integrated environment that assists in developing Android Applications very easily by using a web browser IDE (Integrated Development Environment) that can run over any Android based device, or on an emulator. It is a free drag and drop integrated environment for Android Mobile programming.

The process of building mobile applications starts through the user interface design, in which the different interactive objects and items are inserted in association with their properties and characteristics. Behind the scene of these objects and items goes the implementation phase, where relevant events and actions are coded to run the application. In Google App Inventor, the implementation phase process is done using block programming rather than syntax coding, through which the programming blocks of logic are assembled in order to specify the behavior and the actions of the components.

For the time being, our proposed solution in this research paper will run over several popular Android phone models but can be later customized to run on different mobile platform operating systems models.

6.1. ADIP Mobile Application user interface

The design of our Abu Dhabi Intelligent Parking (ADIP) mobile application interface is described in detail in this

section, supported by all needed figures (A–H). All of the steps for the user interface design are summarized in Table 1 for better visibility.

7. Conclusions

This paper has shown a road map initiative to solve part of Abu Dhabi City's indoor parking issue (Malls Parking). It has tried to toggle the malls' parking searching and reservation by a mobile application technology that mimics the current trend for a fast and better solution of the desired problem. The proposed solution came after a survey conducted by Abu Dhabi citizens regarding searching for a parking space inside a mall parking area and how it may affect their visit to the malls. Many aspects have been discussed and analyzed in the paper, from finding the nearest mall to tracking the current mall parking status in order to make a visit decision and to reserve a parking lot in the desired mall. These issues were considered based on a deep understanding of the current situation of the most famous and well known malls of Abu Dhabi City, and by designing a Mobile Application (ADIP). In conclusion, we found that many people worry about their car parking when they decide to visit a particular mall, especially during weekends, holidays, and even weekdays. However, by utilizing mobile application technologies like the proposed ADIP, based on careful understanding of the current situation, we noticed that the time spent searching for a parking spot inside a mall will be reduced dramatically. It may take only a few seconds to reserve a parking space at any time by using a few clicks on a mobile application, with the possible spatial viewing of the mall parking current status for making a decision. In addition, the suggested idea will assist people to make the right decision for visiting the mall at any time and will make them feel more comfortable, as the algorithm will save their time and efforts.

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